(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

08 OCT 2004

(43) International Publication Date
28 October 2004 (28.10.2004)

PCT

(10) International Publication Number
WO 2004/092495 A2

(51) International Patent Classification[7]: E04B

(21) International Application Number: PCT/US2004/010488

(22) International Filing Date: 6 April 2004 (06.04.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/460,422 7 April 2003 (07.04.2003) US

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(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: SHRAPNEL CONTAINMENT SYSTEM AND METHOD FOR PRODUCING SAME

(57) Abstract: A shrapnel containment system is provided which is adapted to be installed at an interior of a building wall to contain shrapnel from a blast, the system including a panel made of a layer of elastomeric material and fastener elements to fasten the layer to a wall of a structure, with the panel optionally including a fabric reinforcing layer. A method for producing the panel is also provided.

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SHRAPNEL CONTAINMENT SYSTEM AND METHOD FOR PRODUCING SAME

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a system to be installed at an interior of a building wall to contain shrapnel from a blast, and a method for producing such systems.

2. Description of Related Art

In the aftermath of recent terrorist attacks, in which buildings have been targeted for destruction, increased attention has been paid to improving the safety of workers inside such buildings, should further attacks be forthcoming. It has been determined that a main source of damage to articles and injury to persons inside of a building under attack is not necessarily the initial blast of an impact or explosion against the building, but instead is the flying shrapnel (pieces of the building wall) generated by the blast.

It has been determined that improvements in containing this shrapnel can be accomplished by spraying a polymeric liner onto the interior surface of the structural wall of a building. A polymer proposed for this application is a polyurethane material that is sprayed directly onto an interior surface of the structural wall. In existing buildings, this liner would be applied by removing any interior cosmetic wall surface (e.g., drywall), applying the spray coating, and reinstalling the cosmetic wall surface. In new buildings, the liner would be sprayed onto the interior of the structural wall prior to the interior finish work being performed.

The in situ spraying of such a liner is a relatively expensive process, and requires skilled equipment operators and careful containment of the area in which the spraying is being performed. In addition, the polyurethane material has a very rapid set or cure time, on the order of only a few seconds. Thus, when the polyurethane is inadvertently sprayed onto surfaces which are not intended to have a liner thereon, it can be very difficult to remove the material from such surfaces.

Polyurea coating materials are generally known for use in applications where corrosion resistance or abrasion resistance is needed or desired, or in certain waterproofing applications. Certain polyurea coatings also are tear and impact resistant.

It is accordingly a principal object of the present invention to provide a system which improves the safety of a building by providing shrapnel absorption and containment, and which provides improved containment of shrapnel generated from an impact or blast at the wall of a building.

SUMMARY OF THE INVENTION

The above and other objects of the present invention are achieved by producing pre-formed panels which are cut to size, as necessary, and installed onto the interior surface of a structural wall of a building. The panels are produced by spraying a polyurea or other elastomeric material specifically selected to facilitate the production process and the performance of the finished panels, in producing a material having improved elongation and tensile strength properties. Alternatively, the polyurea material or other

elastomeric material may be applied and bonded directly to the interior surface of a structural wall or building.

elastomers such as polysiloxane, polyurethane and polyurea/polyurethane hybrids may be employed as an alternative to polyurea in constructing the panels or in bonding a layer or layers of the material directly to the wall.

The present invention also involves a method for producing shock-resistant panels, including spraying a two-part, high solids, polyurea elastomer material onto a releaseable substrate to a desired thickness, with or without fiber or fabric reinforcement, then allowing the material to cure, and removing the cured panel from the substrate. Panels are then delivered to a building site, and are installed at the interior of the structural walls of the building.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be best understood by reading the ensuing specification in conjunction with the drawing figures, in which like elements are designated by like reference numerals, and wherein:

Fig. 1 schematically illustrates a panel production apparatus according to a preferred embodiment of the present invention.

FIG. 2 is a substantially schematic view of the installation of a shrapnel containment panel at the interior of the structural wall of a building, in accordance with a preferred embodiment of the present invention.

FIG. 3 illustrates a shrapnel containment panel in accordance with a preferred embodiment of the present invention.

FIG. 4 is a cross-sectional view of a panel having a channel member secured at its proiphery.

FIG. 5 is a cross-sectional view of two abutting panels joined at their edges by a panel fastening member according to a preferred embodiment of the present invention.

FIG. 6 is an overhead substantially schematic view of the test layout conducted in accordance with the development of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As illustrated in FIG. 1, a panel substrate 10 is preferably provided as a mold surface onto which a polyurea elastomeric material may be sprayed in producing blast resistant or shrapnel-retarding panels 100 according to the preferred embodiment of the present invention. The substrate 10 may be treated, as necessary, with a release compound, in order to facilitate the removal of cured panels from the substrate.

Employing standard, known, spray application equipment, a two-part, high solids, elastomer composition is sprayed in liquid (uncured) form onto substrate 10. The spray equipment, for illustrative purposes, may include spray nozzle 20, which is connected via flexible tubing 22, to an application pump 24. Reservoir or storage tank 26 may be used to feed the components making up the elastomer composition through feed lines 28, 30, where the components are mixed at valve 32. Spray nozzle 20 may either be manually operated so as to apply the polyurea material over the entire substrate in producing a panel. Alternatively, the spray nozzle (more than one can be used may be mounted to a carriage (not shown) of a known construction that has drive means for moving the nozzle 20 transversely or horizontally, and vertically, to ensure that the composition is applied in an even thickness over the entire substrate. Other spray application arrangements are also feasible,

and the one shown in FIG. 1 is but one example. It is envisioned that, for large scale production, the spray process will be substantially completely automated, with computer control and robotic elements being used to control the spray equipment, including the movement of the sprayers and delivery of the material to be sprayed, and the handling of the panels. The same basic process will, however, likely remain the same.

In a particularly preferred embodiment, the panels may further be enhanced by including a reinforcing layer 102 which may be disposed at either the outer or inner surface of the panel 100, or which may be disposed in the interior of the panel. The method of producing such a panel, with the reinforcing layer being at an interior of the panel, may preferably include placing a reinforcing fabric material against substrate 10, and spraying the polyurea or other sprayable elastomer onto the fabric to a thickness which is approximately one-half the thickness of the finished panel. The fabric 102 with the sprayed-on polyurea is then rotated or flipped such that the polyurea faces the substrate and the fabric 102 faces the spray equipment. A second application or spraying of the polyurea onto the opposite side of the fabric 102 is then effected, to produce a panel of the desired final or finished thickness.

Modifications to this preferred process sequence may be employed. The reinforcing layer can be placed in intimate contact with substrate 10 when it is desired to have the layer at an exterior surface of the panel 100, and the elastomer can be sprayed onto the layer until the desired panel thickness is attained. Where the layer 102 is to be in the interior of the panel 100, the layer may be spaced apart from the substrate 10, with the polyurea being sprayed through the layer to encapsulate the layer 102. Alternatively, a

portion of the panel may be sprayed onto the substrate, and the layer 102 is then introduced, and the remaining thickness of the panel is then sprayed to complete the panel.

Once the spray process is completed, and the polyurea material has either partially or fully cured, the layer is separated from the substrate 10, and thus forms a panel 100.

The panels 100 may thus be essentially mass-produced in an economical manner. This can be accomplished in a true factory setting, or in a portable or makeshift production facility constructed at a building site, if that were found to be comparably economical or desirable for any reason. Panels 100 are then transported to a building which is to be outfitted with these blast-resistant panels.

Interior structural walls 104 of a building to which the panels are to be secured are either left exposed during initial construction or, in a building retrofit, the cosmetic interior wall surfaces are removed to expose the interior surface of the structural wall. The panels 100 are cut to size, as necessary, and are affixed to the interior surface of the wall 104, preferably using any suitable adhesive, or by mechanical attachment. Because the structural wall 104 will commonly be formed either of block or poured concrete, suitable mechanical forms of attachment may include threaded concrete wall anchors, or screw and anchor sets, or nailing with an appropriate concrete-penetrating nail.

FIG. 3 illustrates a preferred embodiment of the panel 100 as it is readied for installation. In this embodiment, panel 100 is bounded at its periphery by channel members 120 which retain the edges of the panel 100 between two

rails 122, 124 positioned at opposite sides (e.g., front and back) of the panel. (see FIG. 4) The channel members, which are preferably made of stainless steel, aid in structurally reinforcing the panels at the edges, adding stiffness thereto. In addition the use of channels at the edges of the panel improves the reliability of mechanical fasteners, such as concrete wall anchors, in securing the panels to the building walls.

FIG. 5 illustrates a further panel fastening member 126 suitable for use when two panels are to be joined to span a distance wider than the width of a single panel. Adjacent edges of two panels are secured to the two rails 128, 130 of this panel fastening member using suitable mechanical fasteners. The rails 128, 130 are offset by a web 132, such that the fastening member retains the two panels in essentially an edge-abutting relationship. The fastening member 126 may be used in addition to, or in lieu of, the channel member 120 at the edges to be joined. The fastening member can be secured to the building wall, as well, by appropriate mechanical fasteners.

An explosive blast, or other type of impact force at the exterior of a building, can cause the structural wall to fracture and generate wall fragments of varying sizes, which are generally referred to as shrapnel. The panels 100, with their improved elongation and tensile strength characteristics, will act to effectively absorb a significant portion of the kinetic energy imparted to the pieces of shrapnel. This absorption of kinetic energy will prevent the shrapnel from flying through the interior of the building. In situations in which the explosive blast also causes the panels 100 to fracture, the kinetic energy absorbed or dissipated by the panels will significantly reduce the amount and/or speed of the shrapnel that may enter the interior of the building.

Persons inside the building are thus better protected against a principal cause of injury resulting from an attack on a building.

The panels are also believed to contribute to the structural integrity of the wall itself, particularly when fastened to the wall by mechanical fasteners at the periphery of the panels.

In order to be effective at absorbing or dissipating the potentially high levels of kinetic energy that may come from an explosion or other concussive event, it is preferred that the panel thickness be in the range of about 100 to about 250 mil. Even more preferably, the panel thickness will be about 180 mil. Panels thicker than 250 mil may also be used, however, it is expected that the possible incremental increase in shrapnel containment or blast resistance afforded by the thicker panels may be outweighed by the increased cost (material cost), in a cost/benefit analysis.

The elastomeric material employed in the shrapnel-containing panels preferably has particular combinations of physical or other material properties in its cured state. Of particular significance are percent elongation at break and tensile strength. The elastomer preferably will have an elongation at break in a range between about 100-800%, and more preferably at the higher end of this range, e.g., 400-800%. The tensile strength of the elastomer is preferably a minimum of 2000 psi.

In addition, the adhesion properties of the elastomer are believed to be important, whether the panels are constructed separately or are formed in place on the walls of the building or other structure to be protected. It is preferred that the elastomer exhibit an adhesion to concrete of 300 psi

minimum (or at concrete failure), and an adhesion to steel of 1200 psi minimum.

As noted previously, polyurea, polysiloxane, polyurethane and polyurea/polyurethane hybrids can produce the desired physical and material properties. Currently, a particularly preferred elastomer is marketed as Envirolastic® AR425, a 100% solids, spray-applied, aromatic polyurea material marketed by the General Polymers division of Sherwin-Williams Company. This material is available as a two-part (isocyanate quasi-polymer; amine mixture with pigment), sprayable material designed principally as a flexible, impact resistant, waterproof coating and lining system.

The Envirolastic® AR425 system has been tested in panels produced having a fabric reinforcement layer. The fabric reinforcement layer provides a framework to which the uncured elastomer will adhere in forming a panel shape. The fabric reinforcement will preferably also contribute to the structural integrity of the panel in resisting blast and in containing shrapnel, particularly in helping restrict the amount of elongation experienced by the elastomer as the energy of the blast or other impact is being absorbed.

To date, the fabrics that have been used in producing panels for testing are produced from aramid or polyester yarns or fibers, with an open grid (opening between warp and fill yarns) on the order of 0.25 in. by 0.25 in., or 0.5 in. by 0.25 in. Smaller or larger grid opening sizes are, however, believed to be suitable for use. The tensile strength of the fabric employed in panels tested to date is on the order of 1200 psi by 1200 psi. Fabric made from Technora and Twaron-brand aramid yarns or fibers produced by Teijin Fibers are believed to be particularly suitable for use in this application.

The shrapnel containment system and method of the present invention can also be in the form of a layer of the elastomeric material applied and bonded directly to the wall or other structure that is to be reinforced. In this instance, the wall would preferably be cleared of loose and foreign materials, with the elastomer applied by spraying, in a manner similar to that employed in spraying the panels onto the panel substrate. The elastomer, as noted above, will preferably be selected to have a bonding strength or adhesion to concrete of 300 psi minimum, and the concrete will generally have a sufficient number of small surface irregularities such that the elastomer will find regions where mechanical attachment enhances the adhesion.

When the system is to have a fabric or fiber reinforcing element, the elastomer may also preferably be partially applied, with the reinforcing element then being positioned, and the remainder of the elastomer layer is then spray-applied. Alternatively, the reinforcing element could first be positioned against the wall, with the entire thickness of the elastomer layer then being applied thereto.

EXAMPLES

Testing of blast-resistant/shrapnel-containment panels in accordance with the present invention have been conducted. The physical test layout (not to scale) is shown in a schematic overhead view in FIG. 6. In FIG. 6, an explosive charge 200 was positioned centrally to four (4) identically constructed concrete block masonry target walls 202, spaced on a 30' radius circle from the explosive. The masonry target walls 202 were constructed having two reinforcing legs 204, which together with the target walls formed a

squared-off "U" shape, such that the target walls 202 facing the explosive charge would have some degree of structural reinforcement, as they generally would in a building.

Panels A, B, and C (thickness not to scale relative to wall thickness) were installed at the interior of three of the walls, while the fourth wall had no panel or lining installed. The panels included stainless steel channels 120 surrounding their peripheries, and were secured to the interior of the walls 202 using concrete anchor fasteners.

All of Panels A, B and C were produced at a nominal thickness of 180 mil of polyurea material (Envirolastic® AR425) having a fabric reinforcement layer disposed therein. Further constructional details of the panels are as follows:

TABLE I

Panel	Elastomer	Fabric Reinforcement
A	AR425, 180 mil	Technora T200 fabric, 0.5 x 0.25" grid opening
B	AR425, 180 mil	Technora T200 fabric, 0.5x0.25" grid opening
C	AR425, 180 mil	Twaron T1000 fabric, 0.25x0.25" grid opening

The explosive charge 200 comprised 42 blocks (52.5 lbs.) of C-4 explosive configured to generate a uniform blast overpressure on the face of each target wall 202. This quantity of C-4 explosive is equivalent to 67.2 pounds of TNT. The charge was elevated four feet above the ground to align it with the center point of each wall (walls 202 were 8 feet in height). The explosive charge was statically detonated, creating a peak incident overpressure of 17.67 psi, and a reflected pressure of 51.22 psi.

Initial post-explosion observations revealed that the unprotected wall (no panel secured to interior) suffered catastrophic structural failure, with virtually none of the concrete of either the target wall 202 or the reinforcing legs 204 remaining in place above the base of the wall. Fragments of the wall, or shrapnel, caused by the blast were found up to 54 feet behind the wall (i.e., to the interior of the wall).

In contrast, the three target walls having the panels installed at the interior surface remained standing, with somewhat varying levels of damage to the concrete blocks. Regions at which the target wall 202 was joined to reinforcing legs 204 appeared to suffer the most damage, due to the stresses induced at those joints by the blast. The target walls themselves contained varying degrees of cracking and fracture.

Inspection of the panels revealed that small areas of a marking paint coating on the interior surfaces of the panel had spalled or been knocked off, presumably by concrete fragments impacting the opposite side of the panel during the explosion. Little or no plastic deformation, and no fracture or perforation, of the panels was observed. No concrete fragments were found behind (to the interior of) the panels.

Upon removal of the panels, fragments of the target walls were found behind each of the test panels. Tables 2-5 present data relating to wall fragments (shrapnel) found subsequent to the test. It is to be noted that no data is provided relative to “Distance from Wall” for the walls having the panels secured thereto, in that none of the fragments passed through the panels.

Table 1: Fragments found behind the Baseline target wall

Fragment No.	Mass (oz)	Distance from wall (ft)
1	1.0	49
2	.4	45.2
3	.3	54
4	.1	41.5
5	.3	41
6	1.7	33
7	13.0	30
8	1.5	24.4
9	1.1	19
10	3.4	19
11	.5	18.5
12	6.7	19
13	.1	19

Table 2: Fragments contained by Test panel T1402

Fragment No.	Mass (oz)
1	.9
2	1.1
3	1.1
4	.2
5	.1

Table 3: Fragments contained by Test panel T1403

Fragment No.	Mass (oz)
1	.5
2	.2
3	1.2
4	.3
5	.1
6	.1
7	2.1
8	.6

Table 4: Fragments contained by Test panel T1404

Fragment No.	Mass (oz)
1	.8
2	1.3
3	5.2

It can thus be seen that the present invention provides an economical means of greatly enhancing the safety of workers and/or equipment or other objects located inside a building or other structure which is subjected to an explosive blast or other form of large impact, which would otherwise send shrapnel of pieces of the wall projecting through the interior of the structure. The system of the present invention can readily be retrofitted into existing buidings and structures, especially when the pre-sprayed panel version is employed, or can be installed in any new building or structure being constructed. The finished interior wall may have an appearance substantially identical to an interior wall not outfitted with the system of the present invention, and thereby no compromise is made with regard to workplace aesthetics.

While principally disclosed as being useful in shielding the interior of a wall and containing shrapnel therefrom in the event of a blast or other impact, the system and method of the present invention, particularly the system in panel form, is believed to provide high levels of resistance to penetration therethrough in more focused or localized impact situations. As such, the panels or the system are expected to be suitable for use as armor "plate" in applications that require energy absorption and resistance to penetration against, for example, generally smaller projectiles fired by rifles and other firearms and guns, including use in defeating or defending against projectiles that are designed to be "armor-piercing" in nature. This property is regarded herein as being encompassed by the terms, "blast resistant", and as used for "shrapnel containment", as those terms are employed herein.

The foregoing description has been provided for illustrative purposes. Variations and modifications to the embodiments described herein may become apparent to persons of ordinary skill in the art upon studying this disclosure, without departing from the spirit and scope of the present invention.

WHAT IS CLAIMED IS:

1. A method for improving blast resistance at an interior of a wall of a structure, comprising:

spraying a layer of an elastomeric material of a predetermined thickness; and

securing said layer to said interior of said wall.

2. A method as set forth in Claim 1, wherein said elastomeric material is selected from the group consisting of polyurea, polysiloxane; polyurethane, and a polyurea/polyurethane hybrid.

3. A method as set forth in Claim 2, wherein said elastomeric material is a polyurea material.

4. A method as set forth in Claim 2, wherein said elastomeric material has an percent elongation at break in a range of about 100-800%, and has a tensile strength greater than about 2000 psi.

5. A method as set forth in Claim 4, wherein said elastomeric material has a percent elongation of break in a range of about 400-800%.

6. A method as set forth in Claim 1, wherein said layer of elastomeric material is produced in a cured panel form and is subsequently secured to said interior or said wall.

7. A method as set forth in Claim 6, wherein said elastomeric material is selected from the group consisting of polyurea, polysiloxane; polyurethane, and a polyurea/polyurethane hybrid.

8. A method as set forth in Claim 7, wherein said elastomeric material is a polyurea material.

9. A method as set forth in Claim 7, wherein said elastomeric material has an percent elongation at break in a range of about 100-800%, and has a tensile strength greater than about 2000 psi.

10. A method as set forth in Claim 9, wherein said elastomeric material has a percent elongation of break in a range of about 400-800%.

11. A method as set forth in Claim 6, wherein said step of spraying said layer of elastomeric material further comprises spraying said elastomeric material onto a fabric reinforcement layer.

12. A method as set forth in Claim 1, wherein said step of spraying said layer of polymeric material comprises spraying said layer directly onto a surface of a wall of a structure.

13. A method as set forth in Claim 12, wherein said step of spraying said layer of elastomeric material further comprises spraying said elastomeric material onto a fabric reinforcement layer.

14. A blast-resistant panel, comprising:

a layer of an elastomeric material having a predetermined thickness, and

fastener elements for securing said elastomeric material layer to a wall of a structure.

15. A blast-resistant panel as set forth in Claim 14, wherein the elastomeric material layer is a material selected from the group consisting of polyurea; polysiloxane; polyurethane, and a polyurea/polyurethane hybrid.

16. A blast-resistant panel as set forth in Claim 15, wherein said elastomeric material is polyurea.

17. A blast-resistant panel as set forth in Claim 14, further comprising a channel member secured to said panel around at least a portion of a periphery thereof.

18. A blast-resistant panel as set forth in Claim14, wherein the elastomeric panel has a thickness in the range of about 100 mil to about 250 mil.

19. A blast-resistant panel as set forth in Claim .18, wherein the elastomeric panel has a thickness of about 180 mil.

20. A blast-resistant panel as set forth in Claim 14, wherein said elastomeric material has a percent elongation at break in a range of about 100-800%.

21. A blast-resistant panel as set forth in Claim 20, wherein said elastomeric material has a percent elongation at break in a range of about 400-800%.

22. A blast-resistant panel as set forth in Claim 20, wherein said elastomeric material has a tensile strength greater that about 2000 psi.

23. A blast-resistant panel as set forth in Claim 14, wherein said panel further comprises a fabric reinforcing layer.

24. A blast-resistant panel as set forth in Claim 16, wherein said panel further comprises a fabric reinforcing layer.

25. A blast-resistant panel as set forth in Claim 24, wherein said fabric reinforcing layer is constructed of aramid fibers.

26. A blast-resistant panel as set forth in Claim 24, wherein said fabric reinforcing layer is constructed of polyester fibers.

27. A system for improving the blast resistance of a structure, comprising:

one or more panels constructed of an elastomeric material sprayed onto a fabric reinforcing layer,

said one or more panels having a steel channel fastened around a periphery thereof

a plurality of fasteners adapted to fasten said steel channel and said one or more panels to a wall of said structure.

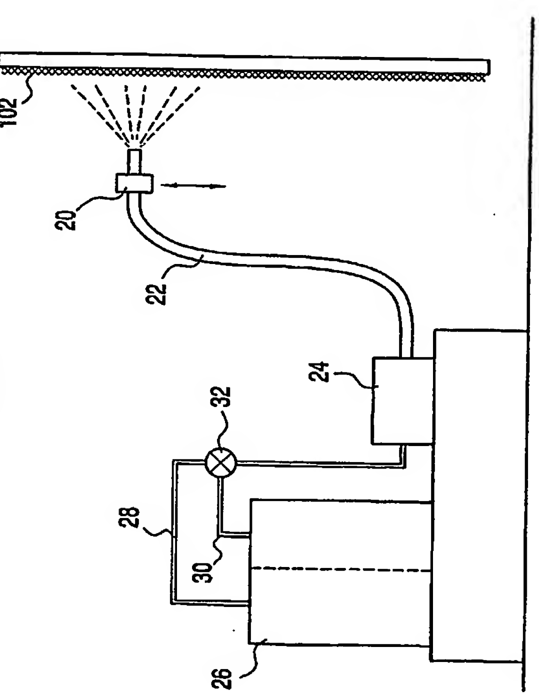

FIG.1

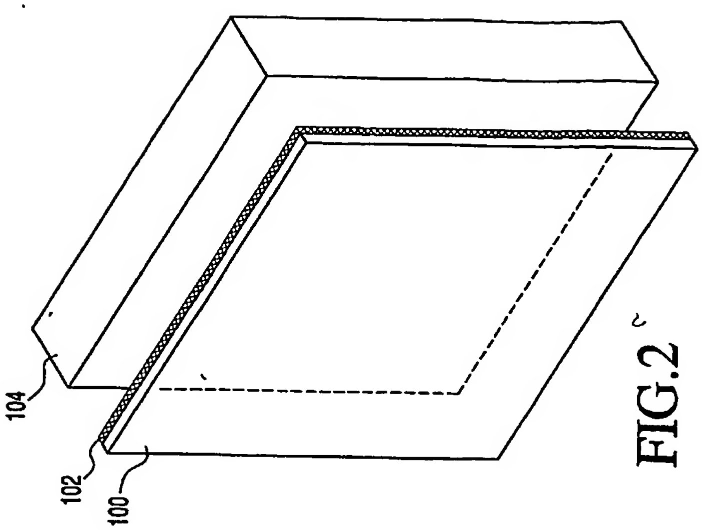

FIG.2

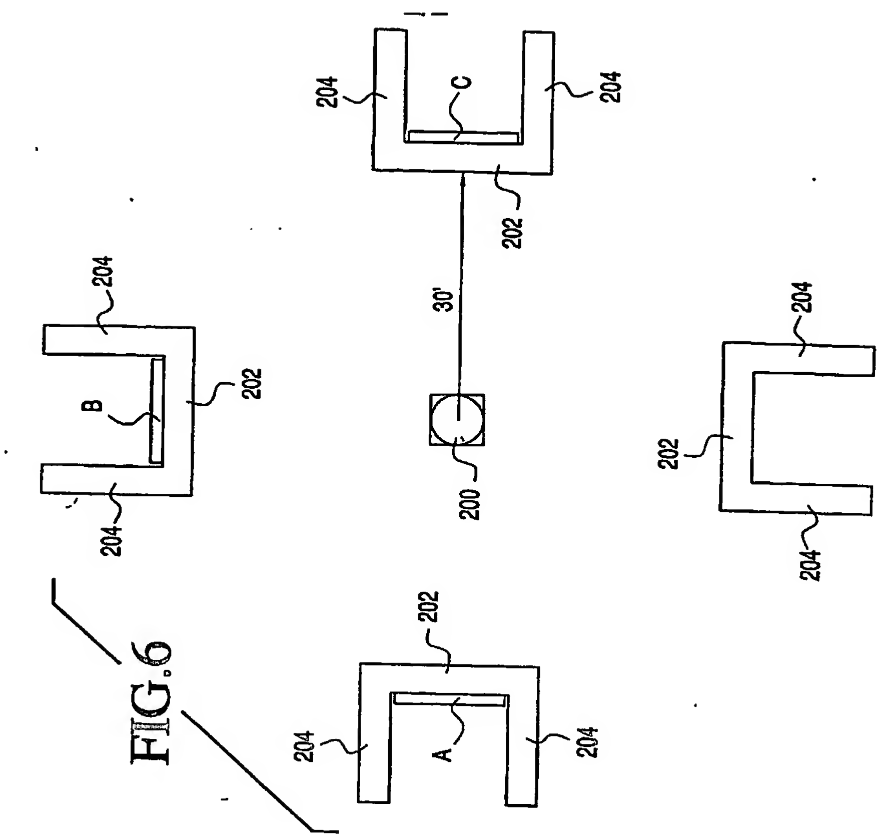

FIG.6

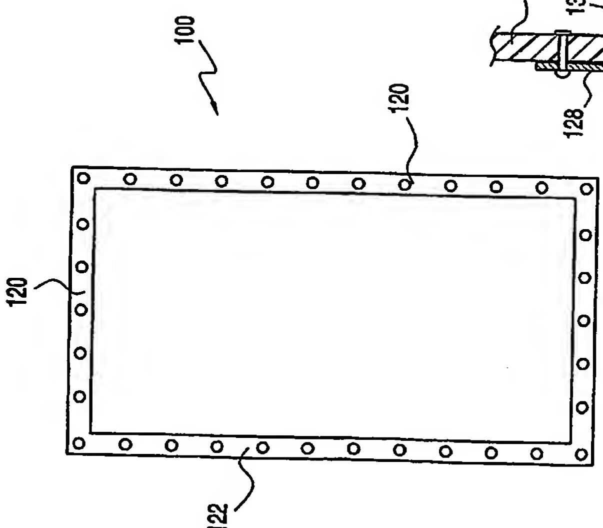

FIG.3

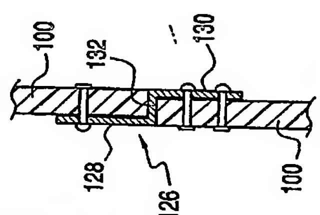

FIG.5

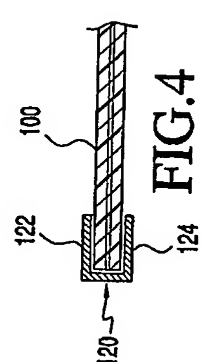

FIG.4